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Failure Analysis

Lower Left Side Waterwall Tube Intermountain Power Project Unit 2

Submitted to:

Intermountain Power Service Corporation

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Structural Integrity Associates

SI Report E-05-327R

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Lower Left Side Waterwall Tube
Intermountain Power Project Unit 2
Intermountain Power Service Corporation
Delta, Utah

Submitted to:

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Introduction

In December 2005, Structural Integrity Associates (SI) received a section of waterwall tubing from the Unit 2 boiler located at the Intermountain Power Project in Delta, Utah that was removed after the element failed in-service. The sample was removed from element 180 of the left side wall, at the 4720-ft. elevation where the side wall ties into the rear hopper slope tubes. The failure was not in the furnace cavity, but was within the lower dead air space located underneath the slope tubes.

The tube section was specified to be SA-213 T2, a ½Mo low alloy steel with a 2.50-inch OD and a minimum wall thickness of 0.260-inch. The tube, which had been in service for 141,649 hours, exhibited severe external wastage resulting from the processes used to remove the sample from the furnace as well as washing from escaping fluid. SI was asked to examine the tube and determine the cause of the leak.

Conclusions

- The cracking in the side wall tube section was due to fatigue that initiated on the external surface of the tube, at the toe of the weld attaching the element to the rear hopper slope tubes.
- As the outer surface of the tubing was severely marred, it could not be conclusively determined that the cracking initiated at the toe of the attachment weld, but it is considered very likely.
- The cyclic stresses that have caused this tube to fail could also be causing similar but less advanced cracking in other tubes. SI recommends that similar sidewall and floor tubing be inspected to determine if other tubes are experiencing similar cracking.

Examination Procedures and Results

The waterwall tube section was visually examined and photographed in the as-received condition, as shown Figure 1. As shown in the close-up view within that figure, the leak was contained to a short crack located adjacent to an angled attachment weld. No significant swelling or other deformation was associated with the failure. In area adjacent to the rupture site, the external surface of the sample exhibited wall loss due to not only erosion/washing from the escaping fluid, but also severe wastage that occurred during the sample removal process. A portion of the tube containing the crack was longitudinally split to allow for an examination of the internal surfaces. As shown in Figure 2, the crack was shorter on the internal surface, indicating that the cracking likely initiated from the OD. The width of the opening and the orientation were similar on both surfaces.

Two cross-sectional samples were removed from the failure location: along the center of the fracture where the crack was through the tube wall and towards the end, where the cracking had not propagated through-wall. The cross-sections were mounted and prepared for metallographic examination using standard laboratory techniques. A cross-sectional view of the crack where it did not propagate through the tube wall thickness is provided in Figure 3. As shown, it was apparent that the crack initiated from the external surface at the toe of the attachment weld. Higher magnification views of the crack tip are shown in Figure 4. The crack was relatively straight with no branching, and transgranular (through-grain), which are characteristic of cracking due to fatigue. The presence of high temperature oxide near the outer surface of the tube suggests that the tubing had operated for some time after the cracking had initiated. The shallow corrosion pitting along the fracture surface did not play a role in the failure.

The high magnification examination of the external and internal surfaces of the tube section remote from the crack revealed minimal wastage, as shown in Figure 5. No evidence of cracks initiating from the internal surface was observed. Figure 6 shows the typical microstructure of the element away from the failure, which consists of pearlite in a ferrite matrix with nonmetallic inclusions scattered throughout. This microstructure is normal for carbon steel waterwall tubing, and showed no signs of overheating damage.

Discussion

The sidewall tube failure is due to fatigue cracking that initiated from the toe of the attachment weld. The relatively straight, transgranular cracking with a few branches is characteristic of fatigue. The presence of high temperature oxide on the cracking near the OD surface indicates that the tube operated for some time with the cracking present prior to the failure event.

Two common sources of the cyclic stresses necessary to initiate and propagate fatigue cracks in attachments similar to this sample are constrained thermal expansion and contraction and vibration due to large stresses applied to one of the connecting elements. Because the cracking is driven by stress, the cracks always propagate from a location of high stress in a direction perpendicular to the direction of principal stress. Since the orientation of the crack in this tube section is angled, following the contour of the attachment weld, it cannot be easily determined if the principal cyclic stress was due to movement of the boiler sidewall due to thermal expansion and contraction issues or due to the movement of the floor tube from falling slag or other shock loads. Either loading type could result in this type of cracking.

The cyclic stresses that have caused this tube to fail could also be causing similar cracking that is not as far advanced in other tubes. As a result, SI recommends that similar furnace sidewall and floor tubing be inspected to determine if other tubes are experiencing similar cracking.

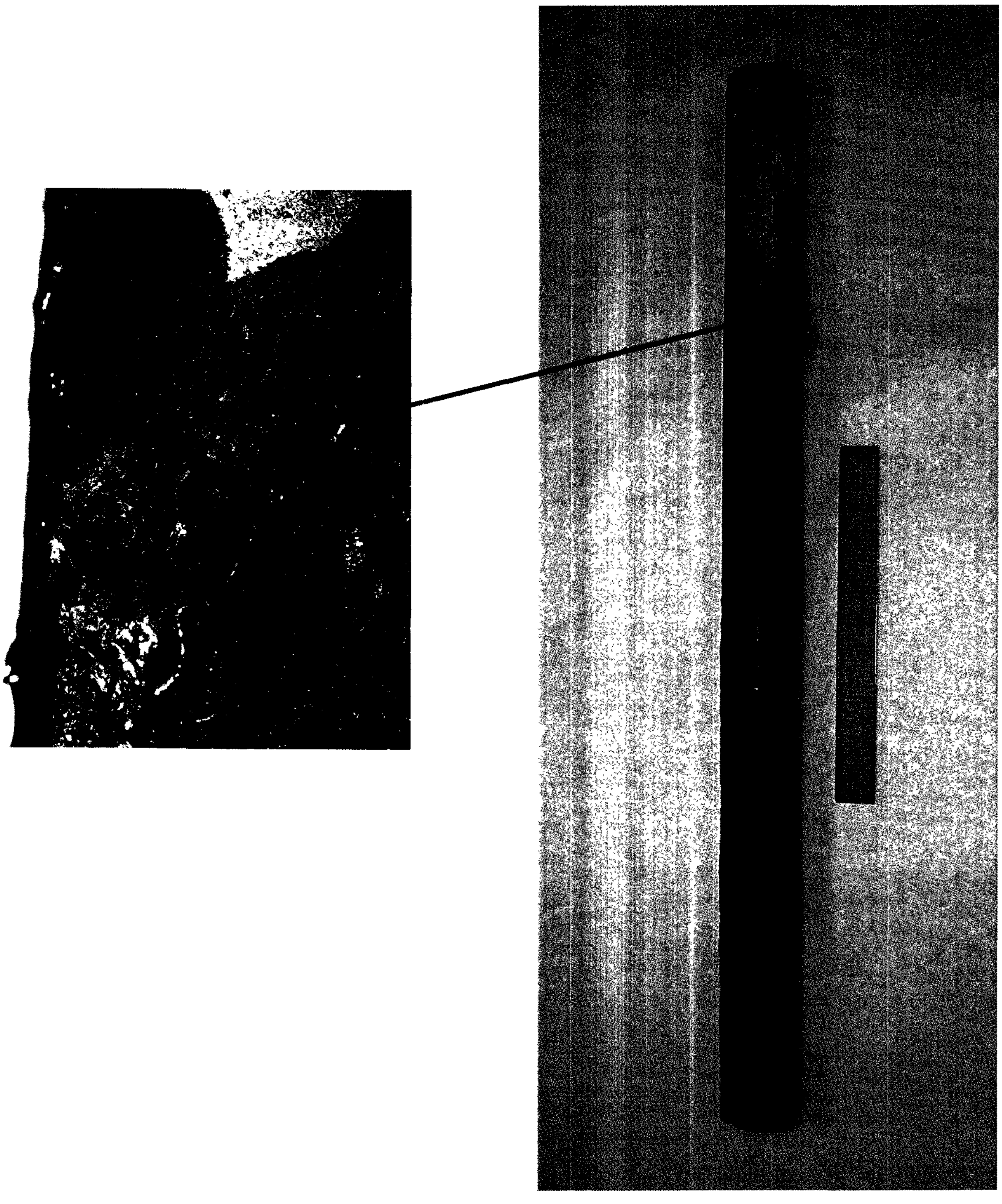


Figure 1. **The waterwall tube section (Element 180) shown in the as-received condition. A closer view of the failure site is shown to the left.**

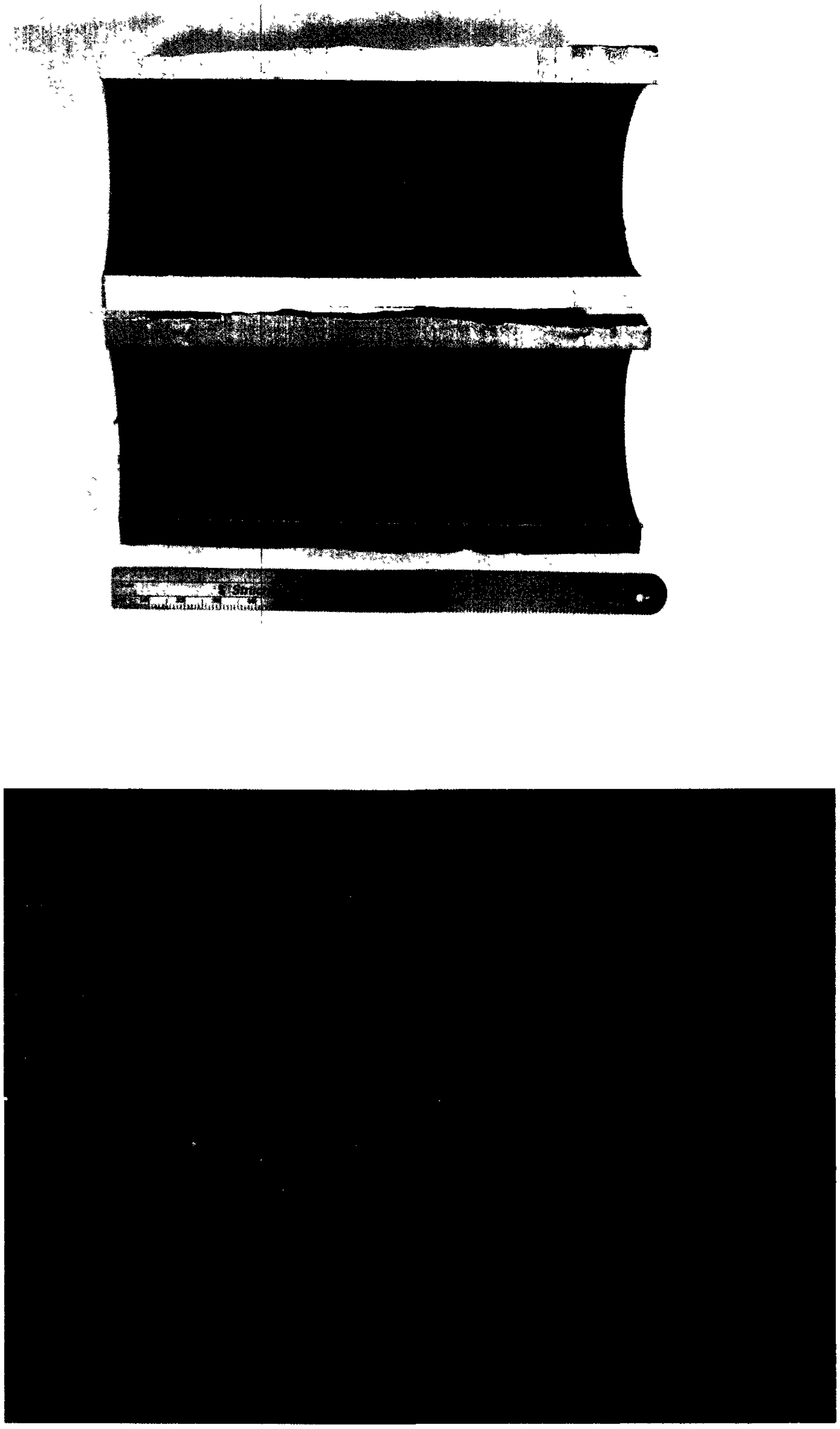
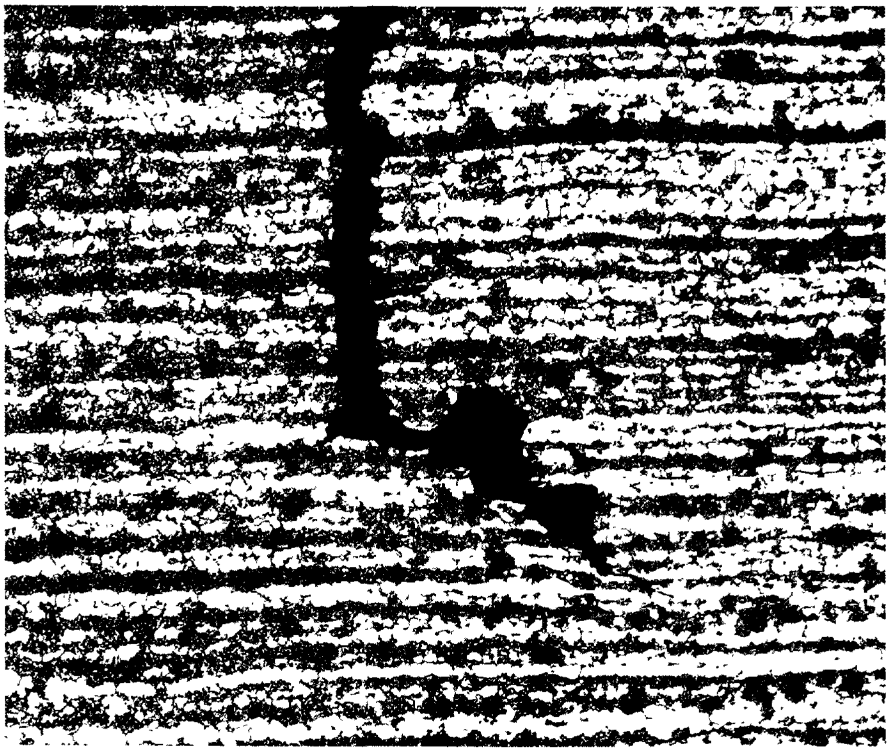


Figure 2. Views of the internal surfaces of the waterwall sample, showing the through-wall crack on the tube ID.

Magnification: 12.5X
Etchant: Nital

Figure 3. A cross-sectional view of the waterwall tube, away from where the crack had propagated through the thickness of the element.



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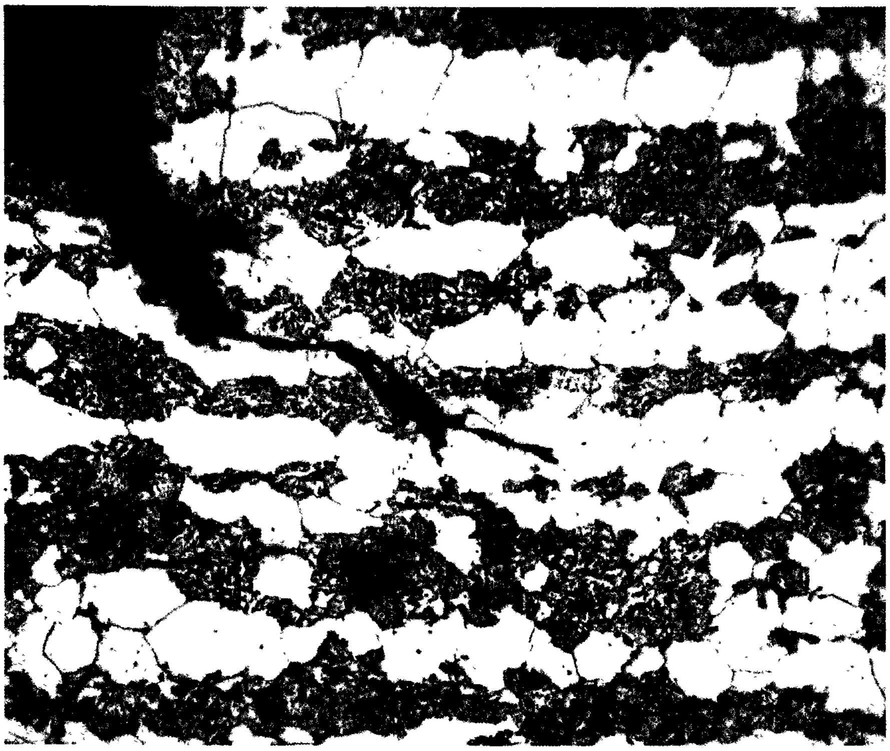

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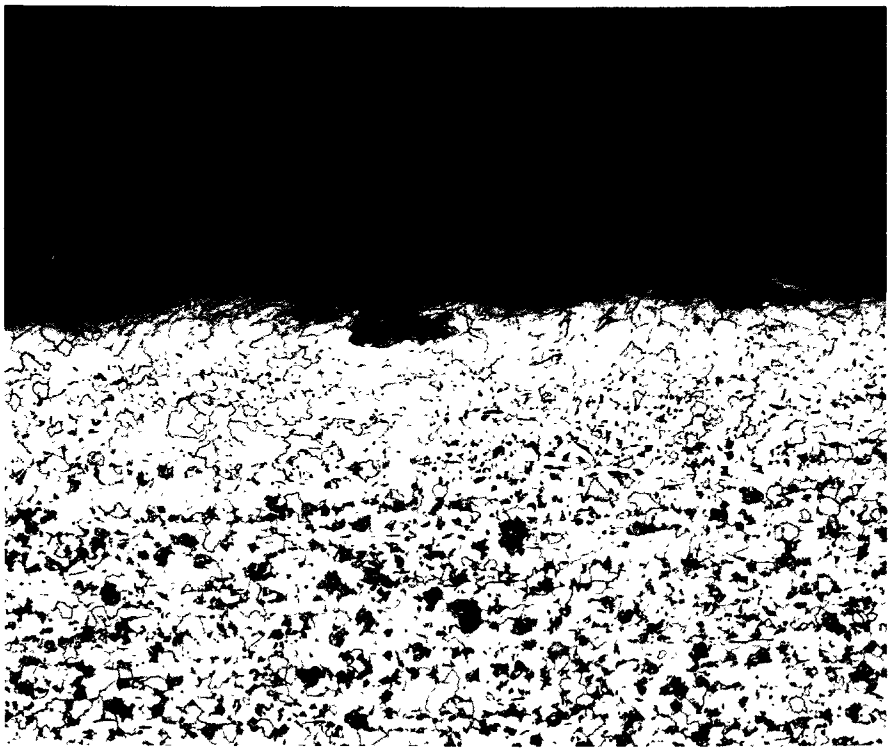
Figure 4. Views of the crack tip showing the transgranular nature of the crack propagation, indicating that while some slight corrosion was evident along the fracture surface, the cracking was driven by stress.



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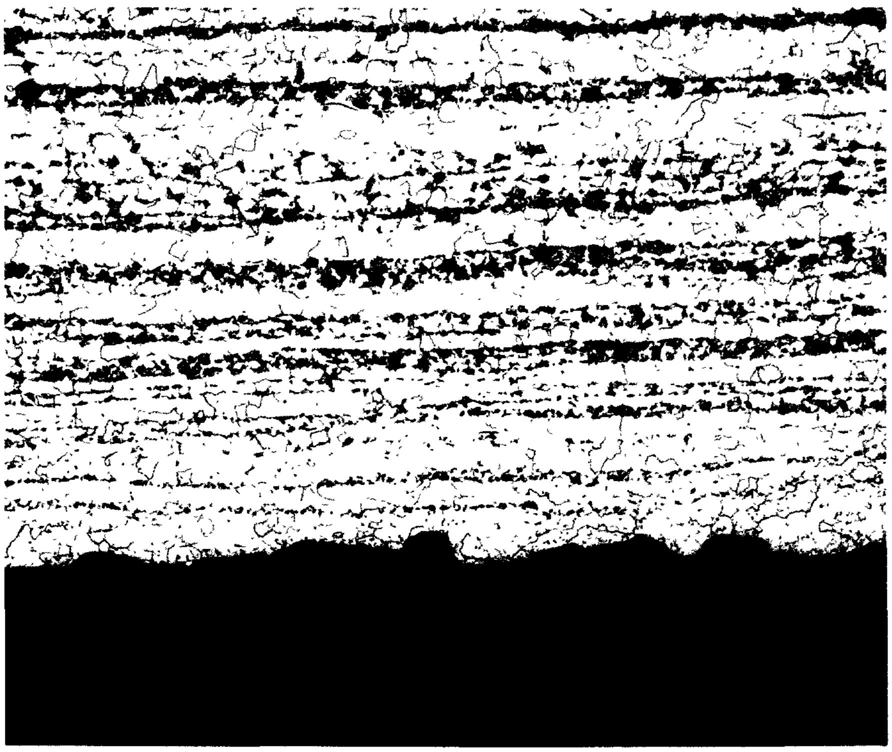

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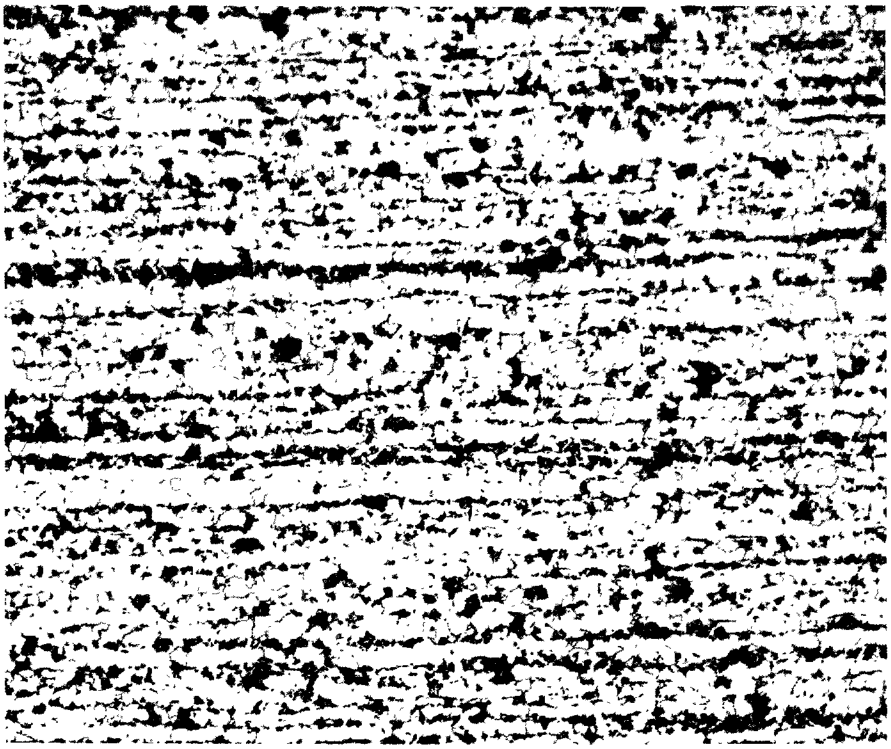
Figure 5. Typical views of the external and internal surfaces of the waterwall tube away from the failure. Note the presence of a decarburized layer on both surfaces, indicating that the tubing has not experienced significant wastage.



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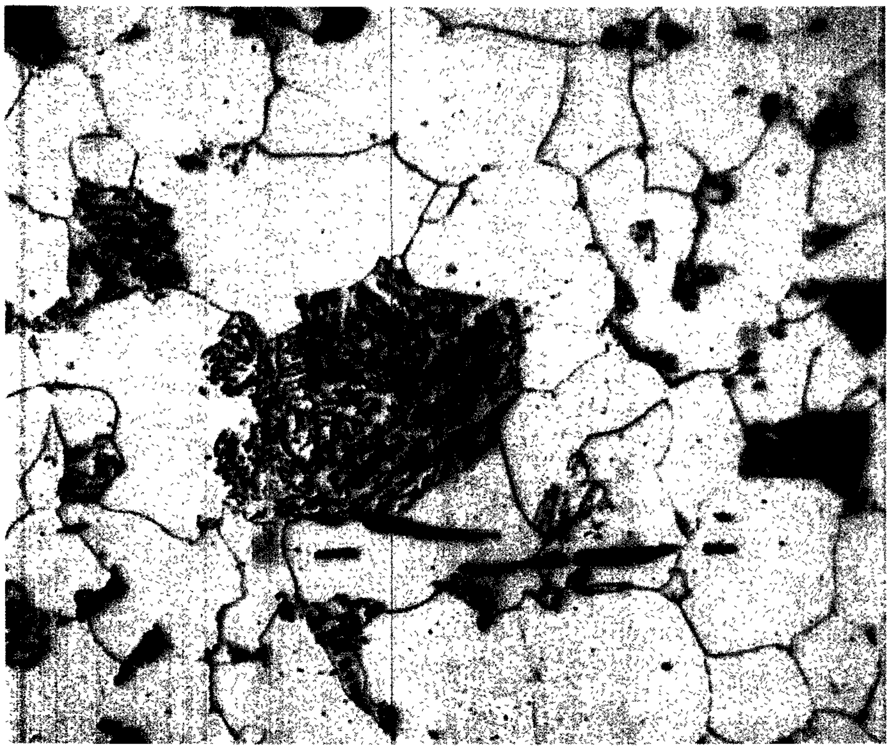

Magnification: 1000X
Etchant: Nital

Figure 6. **Typical views of the waterwall tube microstructure, which consists of intact pearlite colonies and ferrite grains. Some nonmetallic inclusions were scattered throughout the cross-section.**